South Carolina Ambient Groundwater Quality Monitoring Network Annual Report, 2004 Summary

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Bureau of Water

South Carolina Department of Health and Environmental Control

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Ambient Groundwater Monitoring Network

Abstract

An ambient groundwater quality monitoring network has been established in South Carolina for the purpose of obtaining statewide and aquifer-specific baseline values of groundwater quality. This network utilizes selected public, private, and industrial water supply wells for obtaining groundwater samples. Initial sampling was performed in 1987 encompassing 19 wells in four counties. As of 2004, wells from various counties were added from all the major aquifers of South Carolina, and to date South Carolina has a comprehensive network of 116 active wells sampling various depths and locations of the nine major aquifers. The geology of South Carolina influences the quality and composition of the groundwater and dictates the methods of obtaining the water, and is separated neatly along the fall-line running along a SW-NE line through the middle of the state. Wells sampled in the Piedmont tap either the thin layer of saprolite at the surface, or the underlying fractured bedrock, consisting of low to medium grade metamorphic rocks with scattered granitic plutons. Wells sampled to the east of the fall line tap one of the several extensive Coastal Plain aquifers that generally consist of sand, silt or permeable carbonate rocks.

Introduction

The state of South Carolina depends upon its groundwater resources to supply an estimated 40 percent of its residents. To monitor the ambient quality of this valuable resource, a network of existing public and private water supply wells has been established which provide groundwater quality data representing all of the State's major aquifers.

Although a great deal of groundwater quality monitoring is presently being carried out within South Carolina, this is generally at regulated industrial or commercial sites which have known or potential groundwater contamination. In general, these sites are monitored for water quality only in the uppermost (water table) aquifer. The monitoring program described herein has been designed to avoid wells in these areas of known or potential contamination, thereby allowing for the assumption that variability in water chemistry reflects differences in any aquifer's background geochemistry caused by the natural heterogeneity of geologic materials and not anthropogenic causes for changes in aquifer chemistry.

Data derived from this monitoring network has been analyzed for the purpose of identifying variations in water chemistry among the State's major aquifers and developing an understanding of the ambient groundwater quality across South Carolina. The concentrations of certain chemical parameters in a region and/or aquifer may be used as a general indicator against which conditions of potential contamination can be assessed at sites within that area. It is not, however, intended to be used for all site specific comparisons of water quality.

This report is presented in two sections. The first section is an outline of the methods involved in establishing and operating the monitoring network. This includes details concerning well selection, sample collection, chemical analysis, data management, data analysis, and implementation schedules. The second section is a report of the results of the monitoring efforts in the Broad River Basin. Results include a discussion of the geology and hydrogeology of the region, and a discussion of sampling results. Water quality data collected from the entire Ambient Groundwater Quality Network through 2004 is presented in Appendix D.

Objectives

The primary objective of the monitoring network is to develop a baseline for ambient groundwater quality for South Carolina's groundwater resources. Through utilization of this data many other objectives may be achieved. Included among these secondary objectives are:

1) To determine areal variations in regional groundwater quality.
2) To determine aquifer-specific variability in water quality.
3) To detect any significant changes in groundwater quality over time. These time related variations are capable of being determined on both a regional and a statewide level.
4) To supply ambient groundwater quality data for certain areas or aquifers which are in the initial phase of potential contamination investigations.

Methods and Organization

Well Selection

The ambient monitoring network is comprised exclusively of existing public and private water supply wells. Public wells are generally preferred and constitute a majority of the network. Preference is given to public supply wells because of their potential for greater longevity and continuity of ownership in comparison to privately owned water sources.

Initial well selection steps are governed by the availability and completeness of drilling records contained within state files. If complete records exist with respect to location, depth, aquifer, etc., a well may then be further considered for incorporation into the monitoring network. Although past water quality analysis data exist for many network wells, particularly public supply wells, no consideration is given to these data when selecting network wells. This avoidance is necessary to avoid creating a bias in water quality toward chemical constituent concentrations that are higher or lower than anticipated or simply due to lack of documentation on previous quality control.

In order to sample water from "all" portions of the State's major aquifers, well selection criteria also include consideration of which aquifer each well is utilizing, along with the geographic distribution of wells within each aquifer. A final consideration that is addressed when selecting network wells is the presence of, or potential for, contamination within the area. At the time of well sampling, a field check of the area surrounding the well site is performed. If a significant potential contamination source is located in the vicinity, the well is not included in the monitoring network.

Sample Collection and Chemical Analysis

Proper sampling protocol is essential for any monitoring program that is to provide meaningful and accurate data. Nacht (1983) provides a thorough review of monitoring sampling considerations, many of which may be directly applied to an ambient monitoring program. The Department of Health and Environmental Control, Environmental Quality Control (ECQ)

Standard Operating Procedures and Quality Assurance Manual, EQC SOP and QA Manual for short, provides a thorough review of monitoring sampling considerations, many of which may be directly applied to an ambient monitoring program. The EQC SOP and QA Manual includes Sections 5 and 6, "Groundwater Monitoring and Sampling", and "Sampling of Public and Private Water Supplies", respectively, that specifically outline sample capture and preservation. A brief outline of some of the practices and considerations is presented below.

Sampling must be performed in a manner that will allow collection of groundwater that has not been chemically altered by the well system. Public supply wells can normally be sampled from a blow-off pipe or sample cock that is situated between the wellhead and any treatment systems. Private well samples are ideally drawn from the tap closest to the well. Water should be allowed to flow for a time period that is sufficient to recycle water through the entire volume of any pressure tanks in the system if the sample is collected past a pressure tank. Unless a significant volume of water has been pumped from a well immediately prior to sampling, an amount of water equal to or greater than the well volume should also be flushed through the system in order to reduce the likelihood of chemical alteration from well casings, pumps, or residence time in a well.

Samples are collected in appropriately prepared laboratory bottles that are compatible with the chemical constituent being measured. All samples are preserved with proper chemicals [such as sulfuric acid for total organic carbon (TOC), and nitric acid for metals] and refrigerated until submitted to the laboratory for analysis. Proper chain-of-custody protocols and holding times are followed to further ensure the quality of sample results.

Laboratory analyses of water samples cover a wide spectrum of parameters that, as a whole, provide the information that is required to characterize both aquifer-specific groundwater quality. Appendix A presents a list of the chemical parameters that were analyzed. The sampling frequency for all network wells is once every five years.

Any well samples that have chemical concentrations in excess of the National Primary Drinking Water Regulations (Appendix B) will be resampled and analyzed to confirm constituent concentrations. If it is determined that a well is contaminated by anthropogenic causes, the well will be removed from the ambient monitoring network, and the well owner will be referred to proper South Carolina Department of Health and Environmental Control (SCDHEC) personnel for assistance. Future sampling of any wells found to be contaminated will be performed as part of a contamination source investigation.

Data Management and Analysis

The ease with which information can be accessed is a critical factor in determining the success of any monitoring program. In the ambient monitoring network described here, all data related to well information and water quality are stored in an Access database and in STORET, the US Environmental Protection Agency's STOrage and RETrieval system for water quality data. Analyses of network groundwater samples may be presented by way of trilinear (Piper) diagrams, Stiff Diagrams, and graphs. Discussion of various data analyses consider comparisons of water quality to factors such as geology of aquifers, variations of chemical constituent levels among regions, and changes in water quality over time.

Implementation Schedule

The ambient monitoring network was initiated in 1987 on a trial basis in a four county area. At that time, the network included 19 wells, both public and private, and was primarily intended to test and establish the network's methods. In 1988 and 1989, ten and sixteen additional counties were added, respectively. Nineteen wells were added to the network in 1990, another nine wells were added in 1991, and one more in 2000 and 2001. Each year a selection of the wells from a specific aquifer were sampled on a five-year cycle, until 2000. The current strategy involves sampling all represented aquifers within one of the eight major watersheds (fig. 1). These and their scheduled sampling dates are as follows:

2002: **Catawba and Santee** (15 wells): Piedmont Bedrock, Middendorf, Black Creek, and Black Mingo

2003: **Pee Dee** (28 wells): Piedmont Bedrock, Middendorf, Pee Dee, and Black Creek

2004: **Broad** (10 wells): Piedmont Bedrock and Saprolite

2005: **Savannah and Salkehatchie** (25 wells): Piedmont Bedrock, Saprolite, Middendorf, PeeDee/Black Creek, and Floridan

2006: **Saluda and Edisto** (29 wells): Piedmont Bedrock, Saprolite, Middendorf, Black Mingo, and Tertiary Limestone/Floridan

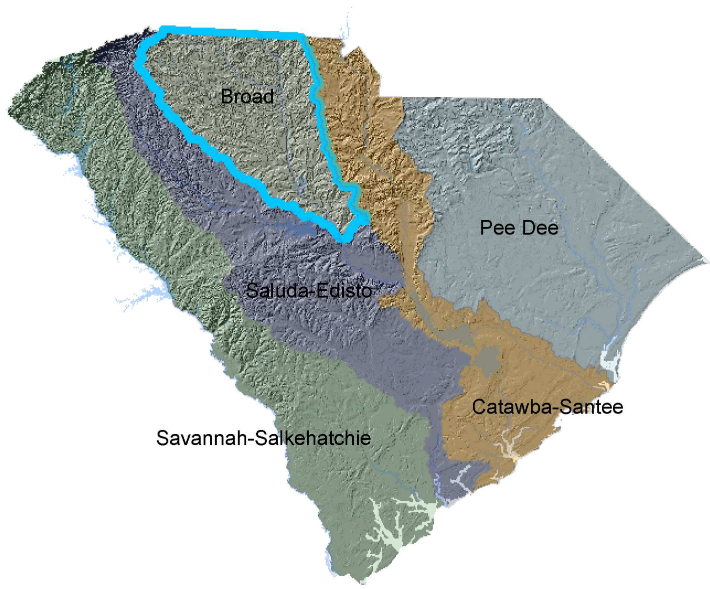

Figure 1: Locations of the major watersheds of South Carolina. This report highlights groundwater sampling conducted in the Broad River Basin (highlighted in blue)

2004 Monitoring Program

Location

The 2004 ambient groundwater quality monitoring consisted of sampling ten (10) wells in the Broad River Basin (fig. 2). Six wells utilized in previous years for monitoring were either abandoned, destroyed, or were built-over by urban development and were unavailable for sampling. All wells sampled during 2004 are located within the Piedmont physiographic province, and outside of the Atlantic Coastal Plain.

The Piedmont region of the Broad River Basin is a plateau of forested rolling hills with tight, dissected river valleys that generally contain small flood plains. Elevations within the basin range from roughly 3000 feet to approximately 500 feet above sea level. The watershed lies between the Catawba Basin to the northeast, and the Saluda Basin to the southwest (fig. 1). Streams generally follow a dendritic pattern and drain to the Broad River and eventually the Atlantic Ocean. The cities of Greenville, located mainly in the Saluda River Basin, and Spartanburg, located in the Broad River Basin, are the major population centers in the area. Although densely populated areas exist within the basin, many areas are only lightly populated, with many small towns and rural agricultural areas.

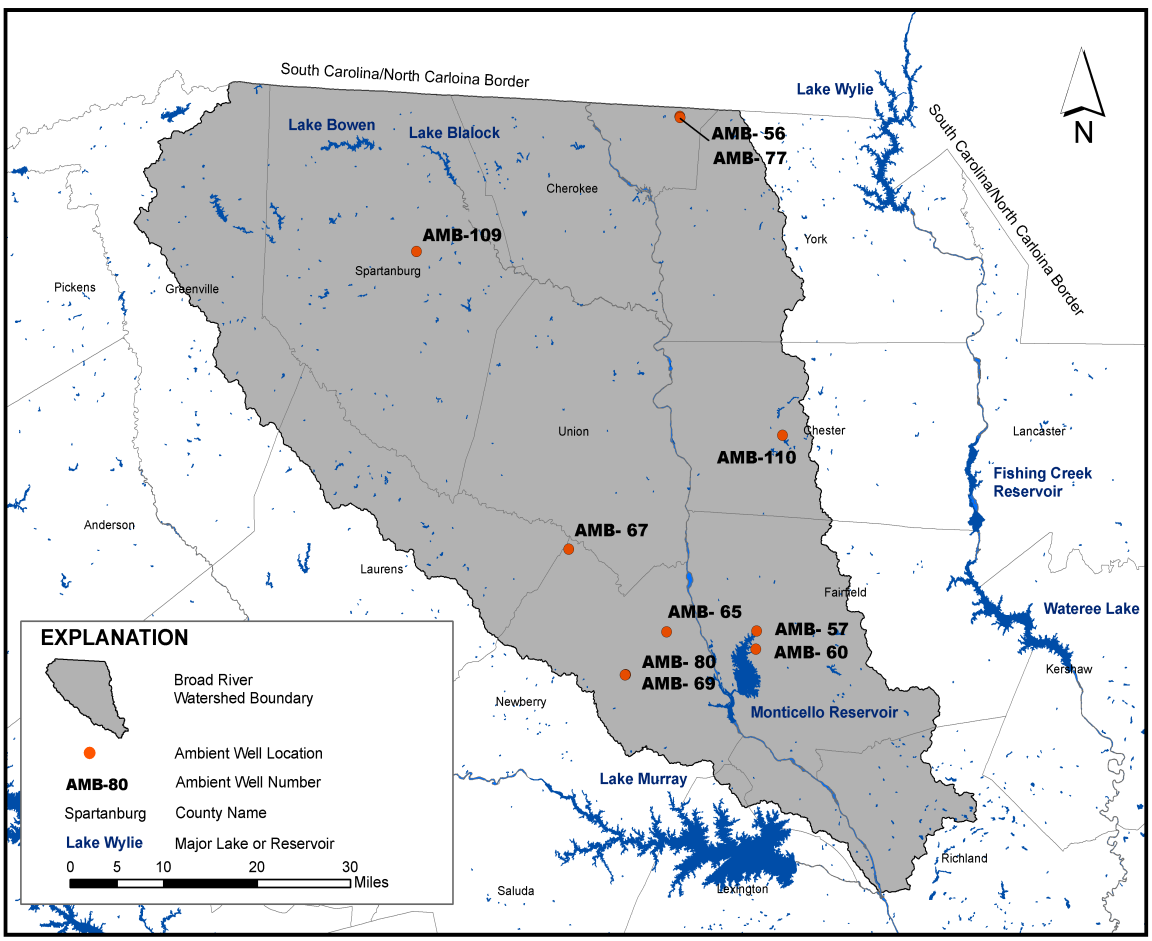

Figure 2: Locations of Wells within the Broad River Basin sampled during 2004

Hydrogeology, and Groundwater Quality of the Broad River Basin

Geology Overview

A complex mosaic of igneous and metamorphic rocks underlies the vast majority of the Broad River Basin, with a tiny portion in the southern section of the watershed being covered by younger, Cretaceous-aged sediments of the Coastal Plain (fig. 3). The majority of rocks in the Piedmont are medium-to-high grade metamorphic rocks such as schist, gneiss, and amphibolite. These rocks are generally stratified and compositionally layered with distinct foliation. In addition, lineaments and fault systems are common in the region, and several major thrust sheets are present in the basin. Numerous granitic plutons and stocks have intruded older metamorphic rocks, and are often marked by areas of higher topography; a result of the massive, resistant nature of these intrusive rocks.

Because of the warm, humid conditions, the crystalline rocks are heavily weathered, and a mantle of the clayey residuum, saprolite, overlies most of the bedrock in the region. As a result of these weathering processes, iron oxide-stained kaolinite and other aluminosilicate clay minerals are the dominant constituents of upland soils in many areas. Modern fluvial sediments generally occupy only the active bed and small floodplains of local streams and rivers.

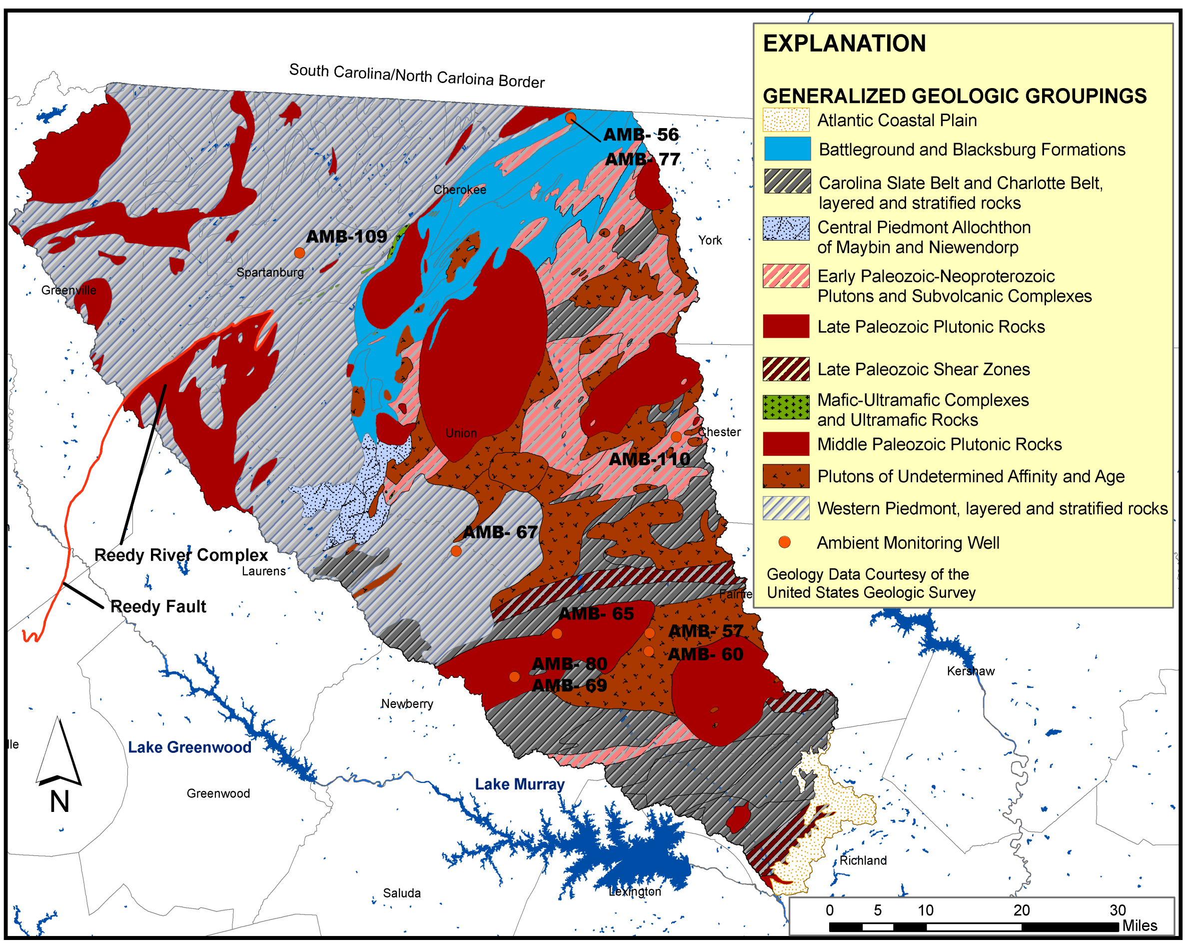

Figure 3: Generalized geology of the Broad River Basin. Only portions of the Reedy Fault are shown, and all other faults are omitted. Geology from Horton and others, 2004.

Crystalline Bedrock Aquifer

Groundwater Occurrence

Groundwater supplies in the Piedmont and Blue Ridge physiographic provinces of South Carolina occur in three types of hydrogeologic environments. These include the unweathered fractured crystalline rocks, the overlying saprolite (fig. 5), and to a limited extent, alluvial valley-fill deposits. Most public supply wells are completed in fractured crystalline igneous and metamorphic rocks, often referred to as "bedrock", while some private wells are simply bored into the overlying saprolite. Although the bedrock exists in a variety of mineralogical assemblages and textures, it has not been hydraulically characterized to an extent that allows designation of separate or distinct aquifers, although some sections of bedrock clearly display greater water-yielding properties than others across South Carolina (Oldham, 1986). For the purposes of this report, all groundwater occurring in the metamorphic and igneous rocks of the Piedmont and Blue Ridge provinces is referred to as either the Piedmont Bedrock aquifer, or the Crystalline Bedrock aquifer.

Figure 4: Flowing artesian well completed in crystalline bedrock of the Piedmont. *(Photo by Randy Kath, State University of West Georgia.)*

Yields from crystalline bedrock vary greatly among wells, depending primarily upon the existence of joints, foliation, and fractures within the rock. Well performance further depends upon the size of fractures and degree of fracture interconnection. Fractures generally occur as the result of stress imposed on the rock mass, and can be found in many different orientations, from vertical to horizontal joint sets. Large fractures, on the order of several inches, can be surprisingly common in some areas, while other locations display tight, poorly connected joints where the rocks are more massive, as in the case of granite or strongly recrystallized metamorphic rocks. Artesian conditions (fig. 4) may occur when well locations are in topographic lows, and fracture orientation is favorable for such conditions.

The overlying saprolite and the transition zone between saprolite and the unaltered bedrock is hydraulically connected with the underlying crystalline rocks and provides the primary source of recharge water to Crystalline Bedrock aquifer system. Some investigators have reported a positive correlation between the thickness of saprolite and soils overlying bedrock to bedrock well yields (Mitchell, 1995). Yields of 4 to 170 gallons per minute (gpm) from the 30 network wells in the Piedmont bedrock have been recorded.

Some of the sampling sites in the Broad River Basin consist of "paired" wells, where one well is completed in the saprolite and an adjacent one in the fractured crystalline bedrock. The wells are considered pairs due to their proximity, and are used for comparing water chemistry between the saturated saprolite and the underlying bedrock system.

Figure 5 (Above): Photograph of saprolite development in gneiss displaying relict banding. Development of saprolite is non-uniform and differential weathering is highly influenced by mineralogy. 10cm card for scale.
Figure 5 (Below): Joint sets and saprolite development with fracture preservation in saprolite (lower right). Both features influence groundwater flow near land surface and in the deeper subsurface. Hammer for scale. (*Photos by Pete Stone, DHEC.)*

Water Quality/Chemistry

The chemistry of groundwater samples is affected by several factors, including the lithology of the bedrock, residence time of the groundwater, and influences by manmade sources of alteration/contamination. Because the lithology of the bedrock differs greatly within the Piedmont, so too does the composition of groundwater. Results of laboratory analyses of samples obtained within the Broad River Basin are presented in tabular form in Table 1, and indicate that calcium and sodium (in that order) are the dominant cations. Generally speaking, groundwater from the Piedmont is usually a calcium carbonate-type water (fig. 6), though significant variation exists.

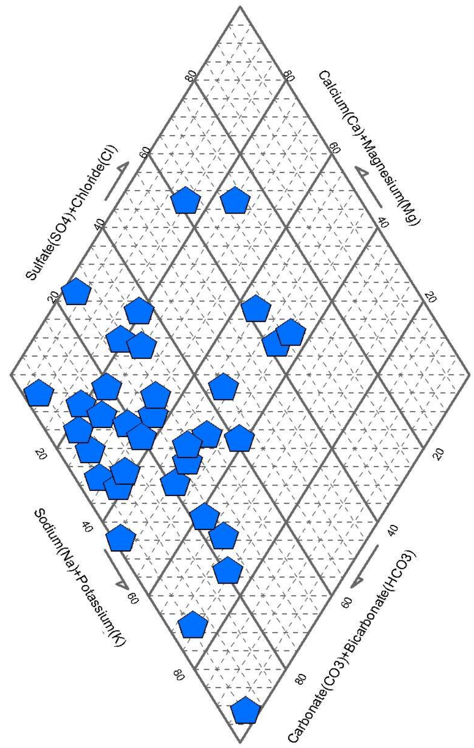

Figure 6: Partial ternary diagram of the relative elemental abundance of samples from the Crystalline Bedrock aquifer in South Carolina.

Analyses indicate that the water samples from 2004 ambient monitoring display great similarity in composition, and are suitable for most purposes, with minor exceptions. Ambient wells AMB-109 and AMB-110 displayed levels of iron in excess of National Secondary Drinking Water Standard (0.3 ppm), though at levels that do not cause health concerns. The non-enforceable Secondary Standard was established for public water systems for aesthetic purposes, and is a guideline for water quality. Wells AMB-110 and AMB-67 exceed the Secondary Standard for manganese (0.05 ppm), and may cause staining of plubming fixtures. Based on the total dissolved solids (TDS), sodium, calcium and magnesium concentrations, the water is suitable for most irrigation purposes and has a low-to-medium salinity hazard. Of all samples processed, AMB-110 from Chester County returned the highest TDS, alkalinity, hardness, and electrical conductivity of all 2004 samples (fig. 7). In addition, chloride, sulfate, total organic carbon (TOC), and some common metals were detected in greater abundance in this well than in any other well in the network. The water obtained from AMB-110 may be influenced by either longer residence time in the host rocks, influence by host rocks of a lithology distinctive from other wells in the network (see fig. 3 for geology), or influence from manmade contaminants.

Based upon analysis of chemical data from the entire network's saprolite/bedrock well pairs indicate a similarity in composition. Minor differences in the concentration of dissolved silica and metals such as calcium, iron and sodium are generally the only exception. Most of the bedrock wells displayed higher concentrations of silica, while the saprolite wells displayed higher concentrations of iron. Figure 8 illustrates the composition of 2004 ambient samples with respect to common cations for well pairs located in Newberry and Fairfield Counties.

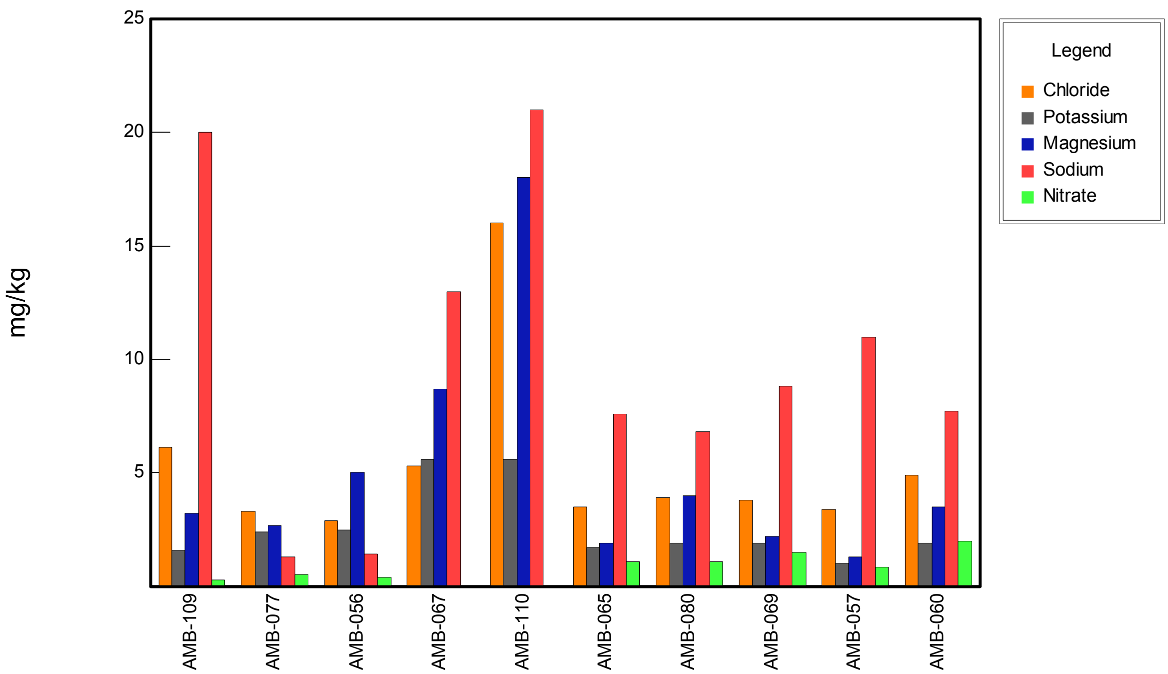

Figure 7: Selected Water quality results from the Broad River Basin, by well number

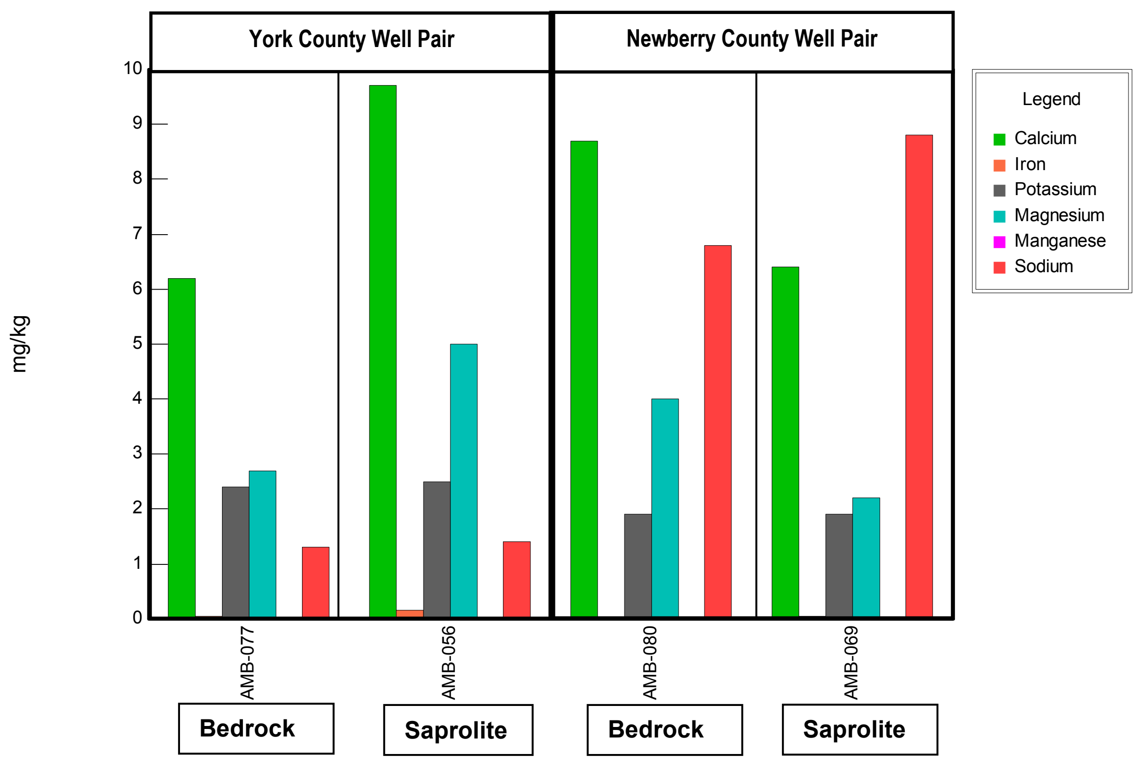

Figure 8: Comparison of selected water quality results from bedrock/saprolite wells pairs within the Broad River Basin

Table 1: Water quality analysis results for 2004 ambient groundwater samples.
[Cond, conductivity, TDS, total dissolved solids, Hardness, as mgCaCo3/kg; ppm, parts per million (equivalent to mg/kg or mg/L), field pH measurements are not available for 2004, and SCDHEC does not report laboratory derived pH measurements]

Sample Information

Well	Location	Latitude	Longitude	County	Sub-Basin	Aquifer	Date
AMB-056	Blacksburg-walker	35.15	-81.43	Cherokee	Broad	Saprolite	7/1/2004
AMB-057	Town of Jenkinsville #11	34.39	-81.29	Fairfield	Broad	Piedmont Bedrock	7/1/2004
AMB-060	Town of Jenkinsville #4	34.36	-81.29	Fairfield	Broad	Piedmont Bedrock	7/1/2004
AMB-065	East Central Newberry County	34.39	-81.46	Newberry	Broad	Piedmont Bedrock	7/1/2004
AMB-067	Town of Whitmire	34.51	-81.64	Newberry	Broad	Piedmont Bedrock	7/1/2004
AMB-069	Newberry-Edna Martin	34.32	-81.53	Newberry	Broad	Saprolite	7/1/2004
AMB-077	Town of Blacksburg	35.15	-81.43	Cherokee	Broad	Piedmont Bedrock	7/1/2004
AMB-080	Newberry	34.32	-81.53	Newberry	Broad	Piedmont Bedrock	7/1/2004
AMB-109	City of Spartanburg	34.95	-81.93	Spartanburg	Broad	Piedmont Bedrock	7/1/2004
AMB-110	Chester State Park	34.68	-81.24	Chester	Broad	Piedmont Bedrock	7/1/2004

General Water Quality Analyses and Physical Properties

Well	Location	pH	Cond	Alk	TDS	Hardness
AMB-056	Blacksburg-walker	--	106	46	73	45
AMB-057	Town of Jenkinsville #11	--	99.4	34	99	20
AMB-060	Town of Jenkinsville #4	--	130	44	110	39
AMB-065	East Central Newberry County	--	121	49	110	38
AMB-067	Town of Whitmire	--	260	120	190	100
AMB-069	Newberry-Edna Martin	--	101	38	100	25
AMB-077	Town of Blacksburg	--	72.7	28	59	27
AMB-080	Newberry	--	110	45	110	38
AMB-109	City of Spartanburg	--	207	84	140	53
AMB-110	Chester State Park	--	530	220	360	220

Inorganics

Well	Location	Pb,ppm	NO_3,ppm	TOC	Cl,ppm	SO_4,ppm	Na,ppm	Ca,ppm	Sr,ppm	TNK,ppm
AMB-056	Blacksburg-walker	<0.050	0.39	4.6	2.9	5.8	1.4	9.7	<0.010	0.27
AMB-057	Town of Jenkinsville #11	<0.050	0.86	4.4	3.4	5.8	11	6.0	0.070	<0.10
AMB-060	Town of Jenkinsville #4	<0.050	2.0	<2.0	4.9	<5.0	7.7	10	0.070	0.16
AMB-065	East Central Newberry County	<0.050	1.1	3.9	3.5	<5.0	7.6	12	0.081	0.56
AMB-067	Town of Whitmire	<0.050	<0.020	9.6	5.3	5.5	13	26	0.15	0.11
AMB-069	Newberry-Edna Martin	<0.050	1.5	5.2	3.8	<5.0	8.8	6.4	0.066	0.30
AMB-077	Town of Blacksburg	<0.050	0.53	4.2	3.3	5.5	1.3	6.2	<0.010	0.43
AMB-080	Newberry	<0.050	1.1	<2.0	3.9	<5.0	6.8	8.7	0.11	0.14
AMB-109	City of Spartanburg	<0.050	0.27	3.4	6.1	10	20	16	0.16	0.11
AMB-110	Chester State Park	<0.050	<0.020	11	16	48	21	59	0.18	0.15

Table 1, continued: Water quality analysis results for 2004 ambient groundwater samples.

Inorganics

Well	Location	Mn,ppm	Zn,ppm	Al,ppm	Be,ppm	B,ppm	Co,ppm	Hg,ppm	Mo,ppm	Se,ppm
AMB-056	Blacksburg-walker	<0.010	<0.010	0.12	<0.0030	<0.10	<0.010	5.0	<0.020	<0.0020
AMB-057	Town of Jenkinsville #11	<0.010	0.018	<0.10	<0.0030	<0.10	<0.010	1.3	<0.020	<0.0020
AMB-060	Town of Jenkinsville #4	<0.010	<0.010	<0.10	<0.0030	<0.10	<0.010	3.5	<0.020	<0.0020
AMB-065	East Central Newberry County	<0.010	0.24	<0.10	<0.0030	<0.10	<0.010	1.9	<0.020	<0.0020
AMB-067	Town of Whitmire	0.11	<0.010	<0.10	<0.0030	<0.10	<0.010	8.7	<0.020	<0.0020
AMB-069	Newberry-Edna Martin	<0.010	0.039	<0.10	<0.0030	<0.10	0.018	2.2	<0.020	<0.0020
AMB-077	Town of Blacksburg	<0.010	0.031	<0.10	<0.0030	<0.10	<0.010	2.7	<0.020	<0.0020
AMB-080	Newberry	<0.010	<0.010	<0.10	<0.0030	<0.10	<0.010	4.0	<0.020	<0.0020
AMB-109	City of Spartanburg	0.049	1.2	0.18	<0.0030	<0.10	<0.010	3.2	<0.020	<0.0020
AMB-110	Chester State Park	0.40	<0.010	<0.10	<0.0030	<0.10	<0.010	18	<0.020	<0.0020

Well	Location	Ag,ppm	Sn,ppm	U,ppm	Cd,ppm	Cr,ppm	Ni,ppm	Li,ppm	Sb,ppm	Si04,ppm
AMB-056	Blacksburg-walker	<0.030	<0.020	<0.10	<0.010	<0.010	<0.020	<0.010	<0.050	10
AMB-057	Town of Jenkinsville #11	<0.030	<0.020	<0.10	<0.010	<0.010	<0.020	0.013	<0.050	55
AMB-060	Town of Jenkinsville #4	<0.030	0.047	<0.10	<0.010	<0.010	<0.020	<0.010	<0.050	42
AMB-065	East Central Newberry County	<0.030	<0.020	<0.10	<0.010	<0.010	<0.020	<0.010	<0.050	41
AMB-067	Town of Whitmire	<0.030	<0.020	<0.10	<0.010	<0.010	<0.020	0.013	<0.050	55
AMB-069	Newberry-Edna Martin	<0.030	0.041	<0.10	<0.010	<0.010	<0.020	<0.010	<0.050	47
AMB-077	Town of Blacksburg	<0.030	<0.020	<0.10	<0.010	<0.010	<0.020	<0.010	<0.050	13
AMB-080	Newberry	<0.030	<0.020	<0.15	<0.010	<0.010	<0.020	<0.010	<0.050	45
AMB-109	City of Spartanburg	<0.030	<0.020	<0.10	<0.010	<0.010	<0.020	<0.010	<0.050	36
AMB-110	Chester State Park	<0.030	0.036	<0.10	<0.010	<0.010	<0.020	<0.010	<0.050	47

Aquifer Vulnerability

The vulnerability of an aquifer to man-made contaminants depends on the degree of confinement and isolation from the land surface afforded to groundwater in a particular geologic setting. Groundwater found in the metamorphic and igneous rocks of the Piedmont is generally unconfined during major portions of its flow path, and therefore, is susceptible to surface contamination. In some cases, water moving through fractures may be isolated from both the atmosphere and near-surface contaminants for considerable amounts of time, but inevitably, that water will eventually mix with “newer” water introduced into the flow regime as recharge from rainfall or streams.

Studies conducted by SCDHEC, in cooperation with the South Carolina Department of Natural Resources (SCDNR) have discovered that many springs and wells in the Broad River Basin, as well as other parts of the Piedmont and Blue Ridge provinces, contain chemicals that are only present in the modern (<60 years) atmosphere, such as tritium (^3H). Tritium has been detected globally at low concentrations in all surface waters since the initiation of nuclear weapons testing in the 1953 (Stone and others, 1989, Stone and others, 2004). The presence of tritium in groundwater, while not necessarily an indicator of contamination, positively indicates whether or not pathways of contamination are present within a groundwater flow system. Based on the presence of tritium from many wells in the Piedmont, most of the Broad River Basin should be considered vulnerable to contamination. Users of private wells are encouraged to have routine testing done on their drinking water supplies.

In addition to tritium, other region-wide studies performed by SCDHEC have found elevated levels of nitrate in some public and private wells in portions the Broad River Basin, though elevated nitrate levels were not detected in 2004 from wells comprising the Ambient Network. SCDHEC studies have shown that the origin of the nitrate may be private septic systems and fertilizers. Elevated nitrate levels in wells are another indication of the vulnerability of the aquifer system to contamination.

Naturally Occurring Radionuclides

In portions of the Broad River Basin naturally occurring radionuclides have been detected in some private and public water supplies, particularly in southeastern Greenville and southern Spartanburg Counties. The highest concentration of dissolved uranium in groundwater occurs in the Simpsonville area near the hydrologic divide between the Broad and Saluda River Watersheds (fig. 1). In a U.S. Environmental Protection Agency-funded study conducted jointly

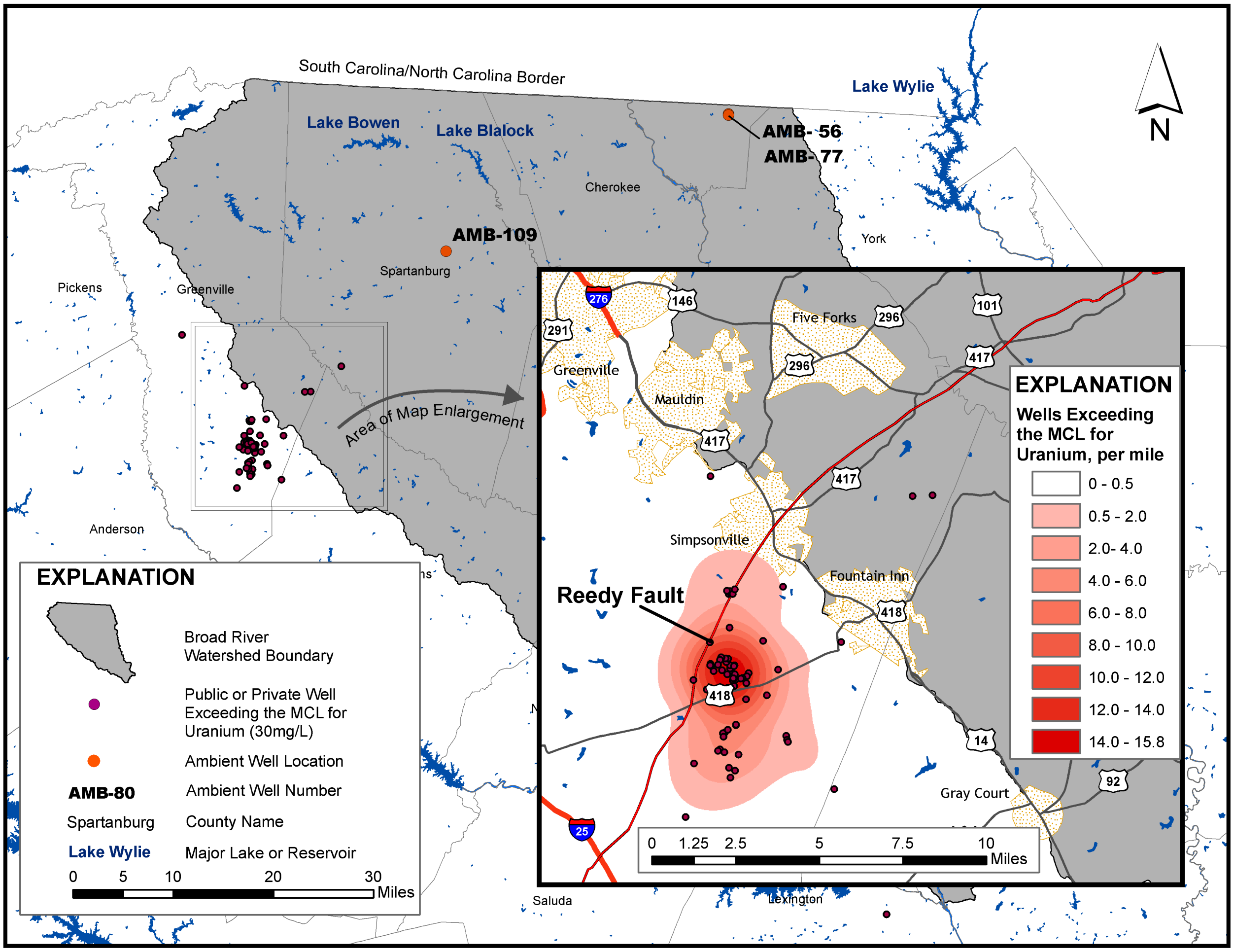

Figure 9: Location and density of wells exceeding the maximum concentration limit (MCL, 30pCi/L) for uranium in the Simpsonville/Fountain Inn area, and relation to Reedy Fault System.

by SCDHEC, SCDNR and Clemson University, a possible source of the radioactive minerals was found. A 700-foot deep well was drilled, and core samples revealed that radionuclides were concentrated in uranium-carbonate minerals (for example, coffinite) in bedrock fractures concentrated along the northern boundary of the Reedy River Complex (fig. 9), and adjacent to the Reedy River Fault System (Warner, 2004). It is believed that these naturally occurring deposits have concentrated in the numerous fractures associated with the regional thrust fault. In addition, it may be possible that the presence of uranium-carbonate minerals in fractures may be symptomatic of a greater source of radioactive minerals in the area.

Studies conducted by Clemson University, Furman University, and the University of South Carolina have discovered localized radioactivity in southern Greenville County that may be the true source of the radionuclides. SCDHEC and university staffs continue to study the occurrence of naturally occurring radionuclides in groundwater and bedrock in the region. As a result of the SCDHEC investigation, public water lines currently serve the majority of the area, and many people who remain on private wells utilize filtration technology to reduce uranium levels in their drinking water. Persons utilizing private wells in the area are urged to have their drinking water tested. Interested individuals should contact the SCDHEC Private Well Program at 1-888-761-5989 to arrange for testing, and information is available at http://www.scdhec.net/eqc/water/html/uranium.html.

Summary

An ambient groundwater quality monitoring network for South Carolina's major aquifers has been outlined and established throughout the State. Network organization includes the consideration of factors such as well selection, sampling intervals and methods, chemical analysis, data management, a network implementation schedule and estimates of overall expenses. The data generated from the groundwater monitoring network provides both a baseline of information to be used in future groundwater investigations, and a better understanding of the chemical nature of one of South Carolina's most essential resources.

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Appendix A: Ambient Monitoring Network Groundwater Quality Parameters

nitrate + nitrite
hardness
chloride
sulfate
TDS (Total Dissolved Solids)
pH
alkalinity
fluoride
TOC (Total Organic Carbon)
specific conductivity
aluminum
beryllium
boron
cobalt
strontium
mercury
molybdenum
TKN (Total Kjehldahl Nitrogen)
silica
zinc
calcium
magnesium
sodium
potassium
arsenic
barium
copper
iron
lead
manganese
selenium
silver
tin
uranium
cadmium
chromium
nickel
antimony
lithium

Appendix B: Maximum Contaminant Levels

The maximum contaminant levels for inorganic chemicals are as follows:

Contaminant	Level (mg/l)
Antimony	0.006
Arsenic	0.05
Barium	2.0
Beryllium	0.004
Cadium	0.005
Chromium	0.10
Fluoride	4.0
Lead	0.015
Mercury	0.002
Nickel	0.1
Nitrate (as N)	10.0
Nitrite (as N)	1.0
Selenium	0.05

Secondary Maximum Contaminant Levels

The secondary maximum contaminant levels are applicable to both community and non-community water systems. The secondary maximum contaminant levels are as follows:

Contaminant	Level
Aluminum	0.05 to .2 mg/l
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corresivity	Noncorrosive
Fluoride	2.0 mg/l
Foaming Agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 threshold odor #
pH	6.5-8.5
Silver	0.10 mg/l
Sulfate	250 mg/l
Total Dissolved Solids (TDS)	500 mg/l
Zinc	5 mg/l

Source: National Primary Drinking Water Regulations – EPA's Drinking Water Standards: http://www.epa.gov/safewater/mcl.html

Appendix C: Ambient Groundwater Quality Network Wells

WELL #	LOCATION	COUNTY	WELL #	LOCATION	COUNTY
01	Bamberg	Bamberg	59	Lake Wateree St Pk	Fairfield
02	Williston	Barnwell	60	Jenkinsville #4	Fairfield
03	Elloree	Orangeburg	61	Mauldin	Greenville
04	Bowman	Orangeburg	62	Fork Shoals	Greenville
05	Lake View #1	Dillon	63	Gilbert	Lexington
06	Latta #1	Dillon	64	Little Mountain	Newberry
07	Johnsonville	Florence	65	East Cntrl Newberry	Newberry
08	McLeod Med Center	Florence	66	Newberry	Newberry
09	Olanta	Florence	67	Whitmire	Newberry
10	Pamplico #1	Florence	68	Chappells	Newberry
11	Andrews #2	Georgetown	69	Newberry	Newberry
12	Georgetown #2	Georgetown	70	Mountain Rest	Oconee
13	Conway #6	Horry	71	Pickens	Pickens
14	Surfside-Poplar St.	Horry	72	Ballentine	Richland
15	Myrtlewood	Horry	73	Union	Union
16	Longs #2	Horry	74	Guthries	York
17	Mullins-Gapway	Marion	75	Abbeville	Abbeville
18	Oakland Plantation	Sumter	76	Starr (deep)	Anderson
19	Watson Correctional	Sumter	77	Blacksburg	Cherokee
20	Kingstree RT 377	Williamsburg	78	Mauldin	Greenville
21	St. Stephens	Berkeley	79	Fork Shoals	Greenville
22	Summerville #5	Dorchester	80	Newberry	Newberry
23	Cainhoy High School	Berkeley	81	Mountain Rest	Oconee
24	Santee Cooper	Berkeley	82	Pickens	Pickens
25	St. Matthews	Calhoun	83	Union	Union
26	Wagener	Aiken	84	McClellanville	Charlestown
27	North Augusta	Aiken	85	Edisto Beach (13)	Colleton
28	Montmorenci-Coucht	Aiken	86	Bennetts Point	Colleton
29	Parris Island	Beaufort	87	North Santee	Georgetown
30	Patrick #1	Chesterfield	88	Socastee	Horry
31	Walterboro (50)	Colleton	89	Fairfax	Allendale
32	Main Street	Darlington	90	Frogmore	Beaufort
33	Hartsville #4	Darlington	91	Sheldon	Beaufort
34	Timmonsville #2	Florence	92	Hilton Head Island	Beaufort
35	S. Ballard Street	Florence	93	Bluffton	Beaufort
36	Elgin	Kershaw	94	Walterboro (29)	Colleton
37	Bethune	Kershaw	95	Edisto Beach (4)	Colleton
38	Camden	Kershaw	96	Lieber Correctional	Dorchester
39	Bishopville #4	Lee	97	Hardeeville	Jasper
40	Swansea	Lexington	98	Ridgeland	Jasper
41	Summit	Lexington	99	Grays	Jasper
42	Hidden Valley	Lexington	100	Cope	Orangeburg
43	Clio	Marlboro	101	Orng Fish Hatchery(2)	Orangeburg
44	Orng Fish Hatchery(1)	Orangeburg	102	Blackville	Barnwell
45	Fort Jackson	Richland	103	Lex-Oak Grove Elem	Lexington
46	Spring Valley	Richland	104	North	Orangeburg
47	Hopkins	Richland	105	Pickney Estates	Sumter
48	North of Eastover	Richland	106	Hamilton Branch	McCormick
49	Sumter Plant 1- #3	Sumter	107	N.W. Edgefield Co.	Edgefield
50	Hemingway	Williamsburg	108	Caesar's Head	Greenville
51	Allendale	Allendale	109	Spartanburg	Spartanburg
52	Eutaw Springs	Orangeburg	110	Chester State Park	Chester
53	Moncks Corner	Berkeley	111	White Bluff Baptist	Lancaster
54	Abbeville	Abbeville	112	Westside Estates	Chesterfield
55	Starr	Anderson	113	Amick Poultry	Saluda
56	Blacksburg	Cherokee	114	WSBH Radio	Hampton
57	Jenkinsville #11	Fairfield	115	McCormick	McCormick
58	Ridgeway	Fairfield	116	Pelion	Lexington